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I. Why the Watering Can:

The watering can is one of the oldest anthropogenic tools still in use today, with early variants dating back to 79 BCE[1]. We believe despite its history, its fundamental design is antiquated. Obviously throughout human history, mankind has developed various techniques to move mass across distances, bounded by constraints. From trivial simple machines to complex logistic networks, yet the design of the watering can has not similarly had a divergence of design for its various constraints, despite ironically being one of the most frequently re-designed tools[2].

All watering cans fundamentally rely on carrying weight and transferring weight off a wrist action. Our design project's purpose is to address the strain experienced in the wrist action of pouring water from a watering can. Wrist strain can be acknowledged[3][4] through a variety of causes, such as damage to the connective tissue from the strain of lifting a heavy weight, contact damage to the hand or utilization of improper technique when handling tools. However, to narrow the constraints of our research, we focus on strain from the repetitive motion of a wrist turn. Specifically, we are targeting a phenomenon, described by Dr. David Wei[5], a nationally renowned hand-and-wrist specialist, wherein due to gardening's nature as being largely a seasonal task undertaken by enthusiasts, people attempt to do several rigorous tasks in a very short amount of time without previous preparation. Our goal is to design a process to reduce the tendonitis and associated pain in the ulnar and radius generated by the rotation of a watering can, while also accommodating the fundamental use-cases of watering cans. We believe that this is the most obvious strain, and the most difficult to solve strain associated in gardening -- Wei notes:

> "Most of us are familiar with the backaches and sore knees that accompany digging, pulling and edging a garden. Those conditions typically resolve within a few hours or a day or two with rest, ice and, possibly, over-the-counter anti-inflammatory medication. However, the hand, wrist and elbow injuries that gardeners can suffer tend to develop over time and don't usually cause pain at the outset. Typically, the pain of sprains, tendinitis and even arthritis is mild at first and often ignored. However, these ailments can develop into serious conditions if left untreated."

1 "Water Pot of Herculaneum, from Villa of the Papyri." *Wikimedia Commons*, Wikimedia Foundation, commons.wikimedia.org/wiki/File:Water-pot-Herculaneum-Villa-of-the-Papyri-Barker-1908.jpg.

2 Etsy is an online marketplace for independent designers. A search for watering cans on Etsy yielded 8,350 results. A search for shovel yielded 6,374 results, screwdriver yielded 4,097, and wrench yielded 7,414 results.

3 https://www.health.harvard.edu/a_to_z/wrist-sprain-a-to-z

4 https://www.physioadvisor.com.au/injuries/wrist-hand/sprained-wrist/

5 https://dailyvoiceplus.com/fairfield/wag/may-2017/the-hidden-hazards-of-gardening/761973/

Furthermore, the poor technique encouraged by traditional watering can design that generates long-term inflammation is best fixed by a redesign of watering technique, as compared to other obvious solutions. To paraphrase Dr. Wei, wrist injuries tend to be chronic, and the fixes for them are approximations at best. A great watering can design must reduce the risk of wrist injuries exclusively through eliminating the techniques that generate wrist inflammation. Improved user engagement, or additional components added to watering cans for comfort, ultimately does not eliminate a wrist-action with causal harms. Likewise, moving a large amount of weight, water especially, requires proper technique or an episodic event can occur that leads to wrist pain or general injury. For example, several watering cans have novel design and use, but an improper user-relationship can still cause a monumental injury if the weight is imbalanced, if the handle isn't as long or uniformly robust as is perceived, etc. While certain watering can designs reduce wrist action and strain, they still can ultimately be associated with poor use or confusing use that leads to episodically catastrophic events, such engaging in a snapping or dragging motion to move the watering can. Moreover, watering cans are used repeatedly over periods of hours, and a strong design is capable of having comfortable aspects over a long period of time, and isn't just effective for short-term watering, i.e. it needs to be ergonomically efficient to refill, carry in different locations, etc. Several watering cans on the market have ergonomic capabilities with rubberized grips and improved form-factor compared to conventional watering cans, but ultimately lack an efficient design for the actual consumer of watering cans, e.g. gardening enthusiasts, who create wrist action and strain by an unwillingness to refill often if the volume is low or the design is poor, or other injuries if the motion of transportation itself involves a poor technique.

As a result of these findings, we felt that we should proceed with a redesign of the conventional watering can, as its frequent use in society, causal association with long-term injury, and penchant for being redesigned yielded an intriguing case study in what is fundamentally an engagement with the age-old question of how to move mass quickly, yet effectively. Simply, by solving wrist-action in watering can use by analysis and application of techniques used to move other mass, we can generate a meaningful improvement to many.

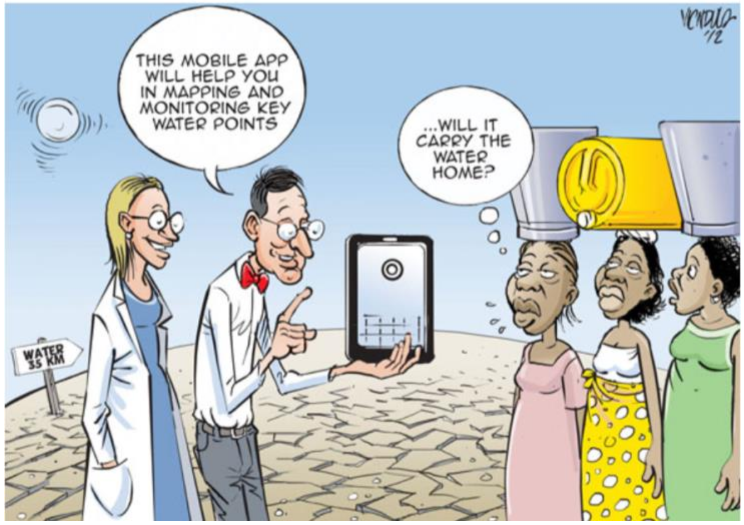
II. Understanding Our Process:

Having assessed our desired task, our group moved onto understanding the assumptions and constraints of our task. We worked through our shared understandings of gardening and informally polled others, and concluded a few core assumptions that drove the design. We concluded that there is a specific age when people garden, or at least seriously enough to consider, e.g. no 5 year old will use our product. Likewise, we assumed to address only common plants that are located in a reachable position, lower torso or below -- higher tended to be watered via hose, half-gallon cans or professional service -- and continued around this idea of watering cans juxtaposed against more professional tools by concluding that individual hobbyist and enthusiast gardeners weren't moving industrial amounts of water, and topped out a maximum can weight of 20 lbs. when carried with both hands. Thereby, we concluded to make our product no heavier than 20lbs at maximum load, to encourage consistently responsible ergonomic uses, while being cost-affordable and easy of manufacture, since our design advantages wouldn't entice the average consumer of the product if the price and availability went significantly beyond a $10 can at Walmart. In fact, after reviewing dozens of ideal watering-can designs, we resolved around a specific watering can sold at Walmart, the *Union Products 2-Gallon Watering Can*[6], and utilized it as a control in our design assumptions, controls and testing -- so much so that we concluded that the two gallon capacity and exact flow rate from the can's rose was already optimal for the consistent gardener, leading to us co-opting those principles as fundamental to our design iterations.

Beyond critical analysis of the watering can ecosystem, we identified fundamental requirements of our design as well. Some were trivial, such as our system must pour water, and must be easy to carry/move around, but these foundational thoughts significantly constrained our ideation. For example, we believed that no matter what, we musn't encumber the process of gardening, which put an end to iterations based around exo-skeleton supports and haptic responses that could have easily solved the core problems of wrist-action and weight management in watering cans. Most paramount, we found that our design must be simple and best use should be obvious. We wanted to evoke something that while ergonomically designed around human factors, didn't obviously intrude on the act of gardening, which we concluded to

6 https://www.walmart.com/ip/Union-Products-2-Gallon-Hunter-Green-Watering-Can/51564579

be a largely individualistic and meditative process. To that end, our engagement with design assumptions centered around a strong ideal of minimalism, and reducing the entire perception of our product to one of a childlike play and curiosity instead of a haggard task, with group discussion being driven around the following image from an early lecture slide[7]:



Significantly, we took advantage of similar research from Professor Harris-Adamson, whose work on improving design around human-factors of moving water in Africa was critical to developing our abstraction beyond a loose understanding of watering cans into a very process-oriented design methodology based on the idea that water is simply one of the masses people have moved forever, and our specific product was best defined as the tool to use whenever other methods of common water transport fail. Notably, we found it very difficult to come up with fundamental understandings of how people specifically interact with their watering cans, identifying a wide range of experiences beyond the conventional bounds of gardening, and a common engagement with the watering can as a source of play and as a general-use tool. From that, we made our most important definition of our task, which was to focus entirely on eliminating wrist action and carrying weight for long periods of time, and in consideration of actual use, we could make our system obvious, with no instruction manual, complicated gauges, hidden systems, or anything other than exactly what somebody would expect and engage in with a watering can. Aside from reflecting on the simple mechanical feedbacks of a conventional watering can, we reduced our understanding of the watering can use beyond a simple information flow, as any task or feedback flow we diagrammed was too constrained, but instead

7 From ‘Week 2: The Design Process’

of being limiting, we opened the possibility of our thinking. Thereby, our product delivered the best principle of being the long-term joy to own that we defined watering-can use as, regardless of if the product was used once a week to address a rose-bush hundreds of yards away from a water source or if it was a daily experience for someone meticulously addressing dozens of plants in a garden.

With that understanding of assumptions, defining our task became easy. The primary task of the watering can is transporting water from one destination to another. A watering can should ideally be a versatile product that allows people to use it in various contexts, such as inside a home or in an outdoor garden, and can be filled up with water and tilted slightly to pour out water from the spout to the desired area.

One would use our product approximately once a day depending on how many plants one owns and how often these plants need to be watered. This means the amount of uses per day can vary from 1 to 2 times per day, or even once every other day, depending on the number of plants and the type of plants that need to be watered. The cycle time of watering one plant should take no longer than 10-15 seconds, and filling up the can should also take under 1 minute, as we don't want our product to be too heavy, and therefore store too much water. The order of tasks to complete one full cycle of watering plants with our product would be as follows: fill up the can (~one minute), roll the can over to your garden (~30 seconds), water the plant (~15 seconds each plant). Needing to refill the can would only be necessary when there is a large amount of plants, and this process would take about another minute and a half to refill. This allows us to estimate a cycle time of about 5 minutes before needing to refill.

We expect our product to be used in a household environment where one is tending to a few houseplants, but also in the scenario of a gardener doing their job and needing to tend to multiple plants everyday. This means our product will be used in an outdoor garden, a front yard, and basically any space that grows plants and allows one to have enough room to navigate rolling our product from plant to plant. One would also need a water source nearby to fill up the can as much as needed.

The actual task hasn't changed much but the people that do it has. In the past, the gardening profession was done by younger to middle-aged men who were fit from doing physical work every day. Now gardens have lots of built-in watering systems and when gardeners water plants manually, they use a hose. Because of this, the demographic of gardeners who use a watering can has shifted from younger men to older men and women.

The future of watering cans is probably going to stay within recreational use and will never come back into the professional world. While the demographic might skew down to a younger audience, the task and operations will remain the same.

III. Surveying and Data-Collection:

After formalizing our understanding and task, we sought to survey current users and reflect on their experiences. We have chose the following questions to inform us in areas where we weren't resolute in our design beliefs. However, we also wanted to understand where people were having the most pain or discomfort when using the watering can, and how we can best remedy this. Person 1 is named Juan. He is in his 40s and tends to people's gardens around his neighborhood as a part time job. Person 2 is an older woman named Betty who only uses the watering can to water her houseplants.

Q1. What is your current comfort level on a scale of 1-10 when using watering cans? Why?

Juan: "I would say a 6 or 7. I tend not to have too many issues when using a watering can, however the only time I feel discomfort tends to be when the can is completely full and I am watering the first plant. I feel more pressure on my wrists at this point and have to slowly pour the water out back and forth to avoid hurting my wrist too much"

Betty: "4 or 5. I have a big issue with watering cans to the point where sometimes I use water bottles to water the plants around my house. The strain on my wrist is too much to bare when the can is full, so sometimes I only fill up a can halfway to avoid feeling excess pain"

Q2. If you had one complaint about the design of a traditional watering can, what would it be?

Juan: "The handle. I find the grip is hard to hold and it is difficult for me to keep the same position with my wrist when pouring out water."

Betty: “I don’t like that I cannot hold the can with 2 hands and pour. When I hold the can with one wrist and pour out, I feel like all the strain is on one point in my body. I feel it would be safer if I could handle it with 2 hands.”

Q3. Have you ever had any wrist injuries?

Juan: “No, no serious injuries. But as someone who has done a lot of gardening I have definitely felt the strain and soreness accumulate over time.”

Betty: “I have broken my right wrist many years ago, but since then not really any major injuries. However, I have many joint problems and I try not to put much strain on my wrists, or knees in fact.”

Q4. How often do you use a watering can?

Juan: “Every day. My job is to tend to people’s backyards and gardens so I am always using a watering can.”

Betty: “A few times a week. I have a few house plants so I try to water them every other day or two. Depending on how much I forget or if I just fill up a bottle, it can be anywhere from 3-4 times a week.”

Q5. How many plants do you usually water per session? How many times do you have to refill this watering can per session?

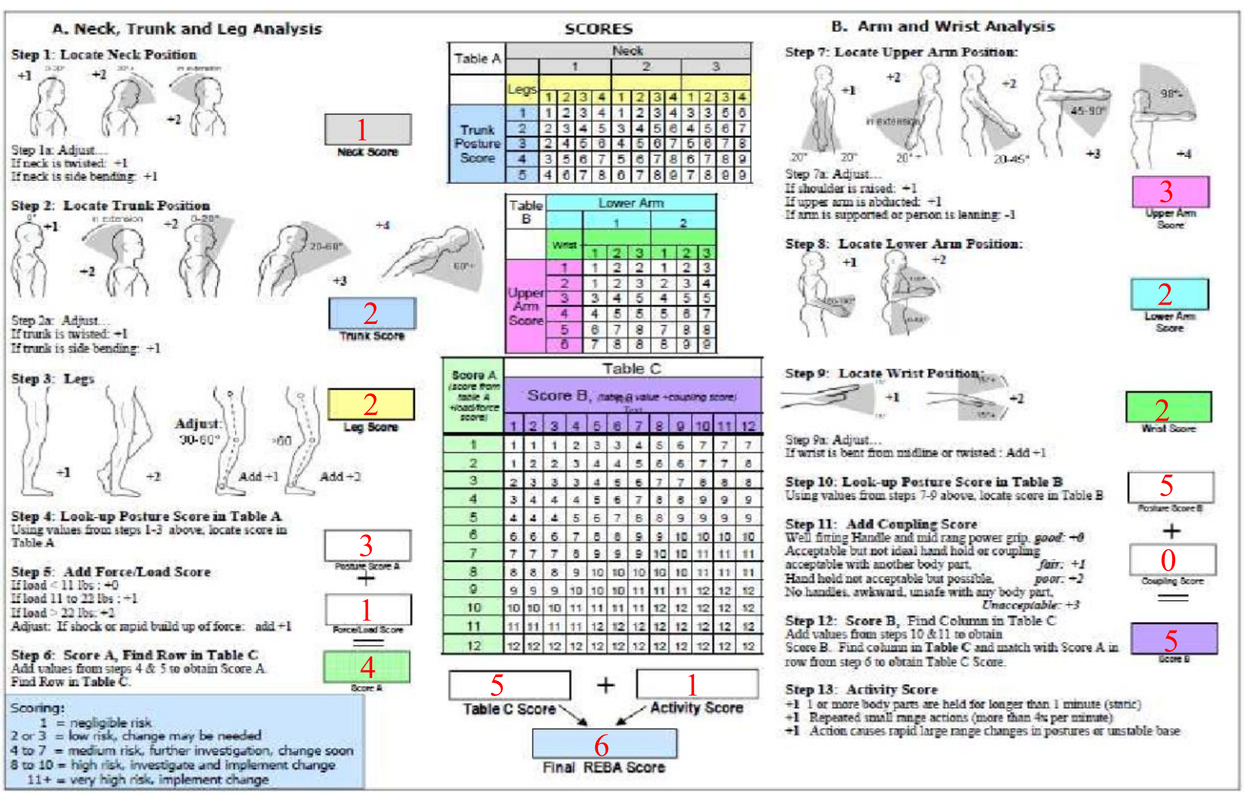
Juan: “Per session, I would say about 10-15. I usually have to refill the can 2 times per session.”

Betty: “About 5 plants. Usually only refill once, if that.”

We observed excessive twisting of the wrist in conventional watering cans, especially if the watering can is heavy when full of water. We envision users of our product being able to keep their wrists in a straight, steady position, and are able to shower their plants with a click of a button, rather than tilting the can in order to pour the water out at the cost of the safety of one's wrists. This product is also especially helpful for people who have problems with their wrist joints, and is made to be an easy-to-use, easy-to-transport, and easy-to-fill product.

In order to measure how successful our product is in meeting our requirements, we used several tools: tracking service time using a tracking simulation (to see how long it takes to deliver water to all plants compared to conventional models), calculating the REBA/RULA score of our model compared to conventional models, designing an A/B test to evaluate qualitative design factors, and measuring the time it takes to move from one location to another using our watering can compared to other watering cans currently on the market.

In terms of exposures, the chief physical exposure in question is the gravitational force placed on the wrist due to the torque of tipping the watering can in order to pour out water. Additionally, there is a force on the shoulder from the generic weight of the water plus the can, which we took into account when designing our product. The chart below portrays the REBA test we did for a conventional watering can:



To provide more context for the chart above, here is a summary explaining our reasoning for the scores given for each step:

Body Part	**Reasoning**	**Score**
Neck Position	Watering cans require little to no movement in the neck beyond looking at whatever plant one is watering	1
Trunk Position	Traditional watering cans often require the user to lean forward slightly when using, leading to a 0-20° trunk angle	2
Leg Position	Watering cans often require the user to bend their legs to adjust for the height of their target plant	2
Force/Load	Most commercial watering cans have a capacity of 2 gallons, which translates to 16.7 lbs.	1
Upper Arm	With traditional watering cans, the arms are required to be extended away from the body	3
Lower Arm	The lower arm must be bent in order to meet the needs of	2

	the user with a traditional watering can design	
Wrist	The wrist flexion is only a (1), but since the wrist must be twisted for traditional watering cans, we add +1	2
Activity	Repeated small range motions, such as bending the wrist repeatedly for each plant	1

Our calculated REBA score for the watering activity is a 6. While this isn't conclusive of a completely dangerous task, it does convey that over hundreds of pours, a simply unsustainable physical motion is required.

IV. Design Parameters:

Our finalized product

Of the hobby gardener population, the average age is 50 years old and 60% are female[8]. Therefore, we designed for the lower end of the bell curve for older women. Our target population is the 5th percentile of women for both grip width as well as carry weight. We chose this because if the grip is a little smaller on a larger person, they will still be able to grip firmly whereas if it's too big one may not be able to get a firm hold. In a similar line of thought, if an older woman is able to maneuver the can, then anybody else should be able to as well.

Our design needs to reduce strain on the wrist for watering can users. The general safety consideration for a task like watering a plant can be measured by REBA, because it is generally about posture and includes factors like arm position and wrist strain. Therefore, the design must lower the REBA score of the activity compared to that of traditional watering cans, and provide a generally better user experience in all ways possible, including ease of lift, transport, and use.

The first and largest issue we noticed with the traditional watering can was the repetitive wrist action involved in pouring the water. To address this issue we designed a can with a spout coming from the bottom so that the head would always be below the water level. To pour water, the user would push a button in the handle to open a valve and let the water flow out. With that we felt as if we had come up with a decent solution to the issue we'd noticed.

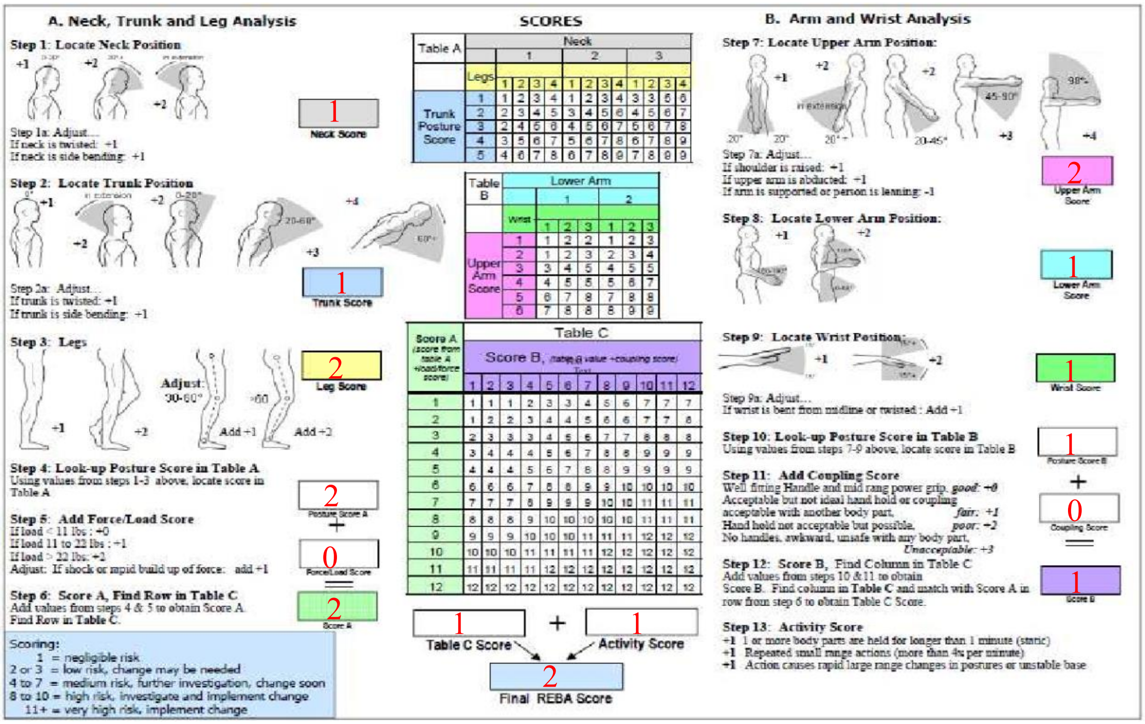
In addressing weight, watering cans on average range from 1.3 - 2.6 gallons, the most common being 2 gallons. 2 gallons of water is equivalent to 16.7 pounds -- this is a significant strain on one arm for a large proportion of our design population. Other solutions use two arms instead of just one, which we took inspiration from and adapted in theme by focusing on distributing the weight among more parts of the body. When someone is watering, they have a free arm, and it can be used in assisting with the task to improve service rates. In the new design, the weight is split between two arms and instead of a wrist action to pour water, it utilizes an up and down motion to rotate on an axis to release water.

Lastly, we realized the user has to carry those 16.7 lbs. from the hose to their plants. To avoid unnecessary effort and strain, we came up with a can that can be rolled behind the user on two large wheels. Along with wrist movements, there is a lot of bending over when filling and picking up the watering can. Without even specifically thinking about our older target population, we wanted to make a can that minimized any backbends no matter who you are. To

8 https://www.targetmarketingmag.com/article/gardeners-28720/all/?fbclid=IwAR2D4OiaBy1t_UDV5NSKbooeHF4yBBvxE4FMfJucxIp90Th-xt-u1ssw9ag

do that we created a long spout which can be pulled up from a standing position so that the user never has to bend over.

Likewise, in evaluating our design, we calculated a REBA score and compared to the conventional can’s score.



Body Part	Reasoning	Score
Neck Position	Watering cans require little to no movement in the neck beyond looking at whatever plant one is watering	1
*Trunk Position**	The new design allows the user to maintain a straight back while using	1
Leg Position	Watering cans often require the user to bend their legs to	2

	adjust for the height of their target plant	
*Force/Load**	The can is now supported by two arms making the load on each 8.35lbs	0
*Upper Arm**	Based on the new grip positioning, the angle of the upper arm shifts down	2
*Lower Arm**	The lower arm bends within 80-100 to support the new can	1
*Wrist**	No longer any need to twist the wrist with the new cm t design	1
Activity	Repeated small range motions, such as bending the wrist repeatedly for each plant	1

V. Reflections:

When choosing a design to bring to realization, we mostly discussed how we can best address the issues we found during the abstraction phase without creating any new ones. We had a few different ideas, all had some pros and cons, all addressed the major issue with watering cans, but only a few really seemed to have the ability to really help remedy all of the issues we discussed. When choosing one of our designs to see all the way through. We decided on one that addressed and alleviated as many issues with the whole process of using a watering can versus one that perfectly remedied one issue, but left many unchanged.

The most successful aspect of our final design is that we have removed the need to have one isolated area carrying the heavy load of a full watering can, as well as removing the need to bend over and pick up the watering can throughout this process. With our two handed grip model, the weight of the can is now spread out among both hands, minimizing the strain on ones wrist when watering their plants. We also made the can one that you can roll around, eliminating the need to bend over and pick up a full watering can with one hand and walking it over to your plants. The unintended limitations we have realized is that you need two free hands when using our product. Before, you may have been able to use your free hand to open certain doors or move your plants around, now you need both hands to use our product. Also, you need to be able to have enough room to roll the can around.

The most challenging stage of the design process for us was definitely the abstraction stage. The abstraction stage is really where you are deciding why there is a need for your design, the biggest problems with the traditional design, how you can tell the design is working, and what data do you have to measure if it is successful or not. These are the most important aspects when designing a tool, and also take the most amount of time and research to ensure you are going down the right path. Although the abstraction stage is very time consuming, it really makes the conceptualization and realization stage that much more rewarding. Being able to recognize the issues with past designs, and converting that into actual prototypes and ideas on how to improve is a very rewarding process. By realizing the issues and pitfalls of previous designs, you can take matters in your own hands to make an effort towards fixing these problems. It really puts an emphasis on the fact that if you want something done better, make sure you know exactly what the problem is and all the steps you need to take in order to improve it.

Another challenging aspect of the design process came during the conceptualization process, specifically when developing prototypes. After collecting data and identifying the biggest problems with traditional watering cans during the abstraction stage, we had many different ideas on how to improve the design. We were able to address the issues with wrist strain in many different ways, so the next challenging was figuring out which design would best remedy this problem, without creating another problem in the process. We had about three options, a couple were very simple but addressed the issue, and one was really a different design that was the biggest change from the current design. After much discussion and experimentation with REBA and various other measurements, we decided to go with the design that requires two hands because it eliminates the wrist strain, and spreads out the weight of the can over more than one isolated area. We also realized that most people aren't doing anything with their off hand when watering plants, so it is beneficial to use both and avoid pressure on joints. After choosing this design and designing it on Rhinoceros 3D, it was very rewarding to see our idea and sketch come to life.

When we set out to redesign a watering can, we knew clearly what the problems with the age-old design were. Traditional watering cans are difficult to carry, and the pouring motion can be uncomfortable at first and damaging with repetition. Though it was not easy to develop a design that would improve in these areas, our idea eventually became reality. A gravity-action watering can that is levered with an ergonomic handle is precisely what the hobby gardening community needs. This is a group comprised largely of older people for whom any musculoskeletal risk factors will become magnified. Our design will be easier to transport because of its wheeling system, will not require an awkward posture to lift, and will pour using a system that is as low-risk as possible when it comes to wrist torsion. The decreases in risk factors were measured using the REBA test, which indicates an improvement to a low-risk activity. As such, we met all of our goals and stayed true to the spirit of what we envisioned when we began redesigning a watering can. There are a few things we would like to improve given more time, such as a stand to facilitate storage, but given our time constraints we are pleased that the most critical elements of our design were realized.